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X.—*Proposed Railway Route across the Andes, from Caldera in Chile to Rosario on the Parana, viâ Cordova; with Report of Mr. E. A. Flint's Survey.* By W. WHEELWRIGHT, Esq., F.R.G.S.

Read, January 23rd, 1860.

HAVING been engaged for several years in introducing and constructing railways in Chile (which is a broken and mountainous country), it became necessary to adopt a system of steep gradients and sharp curves, in order to accomplish these objects economically.

In the year 1842 I proposed to the Government of Chile the construction of a railway from Valparaiso to Santiago, a distance of 110 miles, and to extend it afterwards to Talca and Talcahuano. After repeated surveys, a line was obtained over the first-named route with practical gradients, and these railways are now in progress.

In 1849 I undertook and had constructed a railway from the port of Caldera, in the north of Chile, to Copiapo, a distance of $50\frac{1}{2}$ miles, with a maximum gradient of 60 feet per mile, and terminating at an elevation of 1327 feet above the sea.

In 1854 I projected and had carried out a railway from the city of Copiapo to Sabellon, a distance of 25 miles, with a maximum gradient of 63 feet per mile and a total elevation of 2193 feet above the sea.

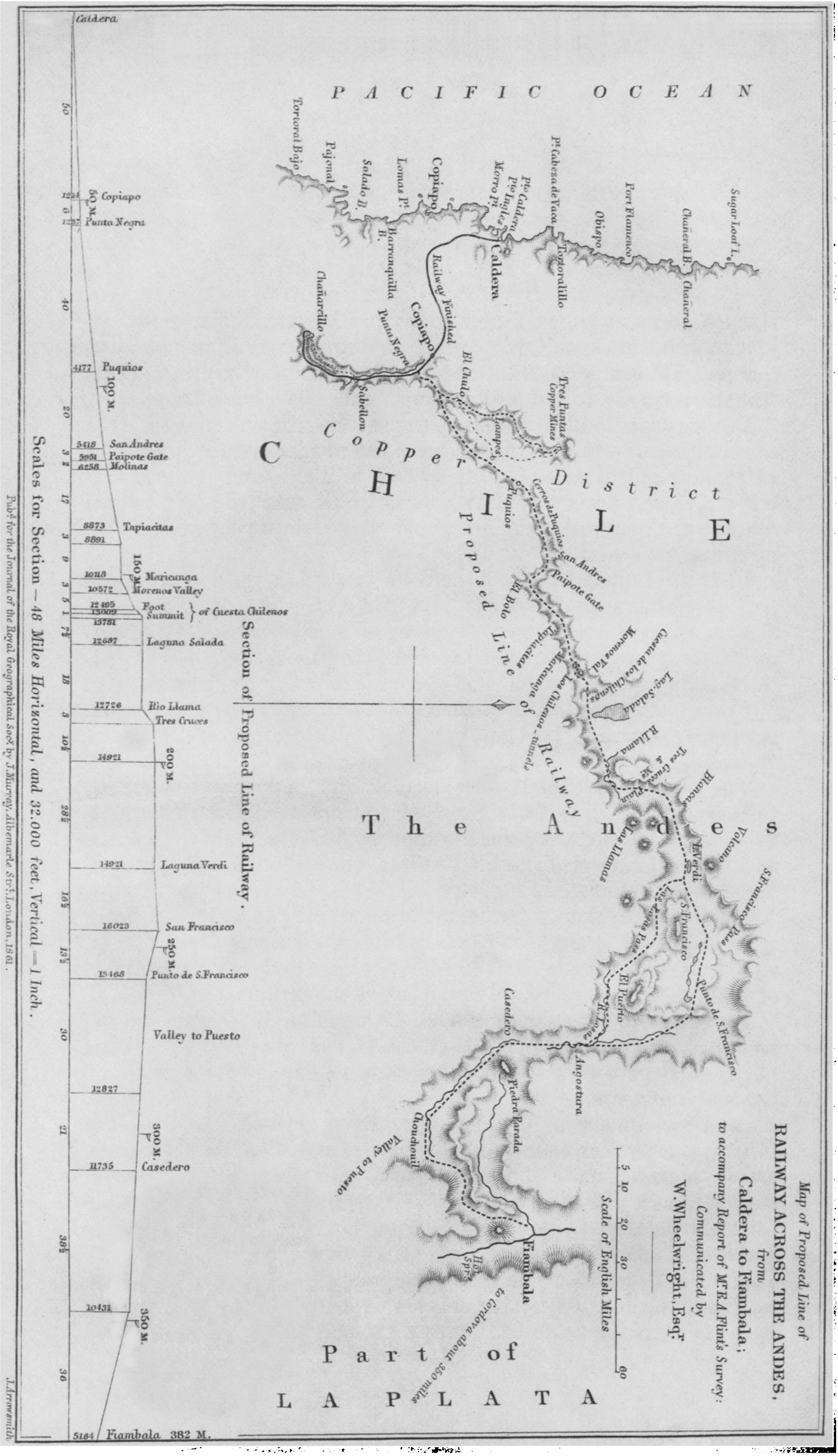
The same year (1854) I undertook and had surveyed a continuation of the line from Sabellon to Chanarcillo, a distance of $26\frac{6}{10}$ miles, surmounting an elevation of 4470 feet above the sea, with a maximum gradient of 250 feet per mile. This railway is about being completed.

At the same time I projected another railway, 60 miles long, from Copiapo to the great northern mining district of Tres Puntos, with a maximum gradient of 152 feet per mile, and with an elevation of 6600 feet above the level of the sea at the terminus.

Having been thus far successful, I was induced to entertain the hope that practical gradients might be had across the Andes to the plains of Buenos Ayres, and I resolved to employ and organise a corps of engineers for this object.

As a preliminary step, I engaged the services of Don Nicholas Naranja, as pioneer, to take barometrical observations on his journey across (he being on his way to England *viâ* Buenos Ayres), to send me his report, and also to inform me how far the road was available for a carriage, as I intended to accompany the expedition with my family and meet him at Cordova. Unfortunately the gentleman to whom I had confided the enterprise was called away, and I was reluctantly compelled to abandon the expedition.

Señor Naranja, however, fulfilled his part to my entire satisfac-



Map of Proposed Line of
RAILWAY ACROSS THE ANDES,
from
Caldera to Fiambala;
to accompany Report of Mr. E. A. Flint's Survey:
Communicated by
W. Wheelwright, Esqr.

Scales for Section – 48 Miles Horizontal, and 32.000 feet, Vertical = 1 Inch.

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tion: his observations were accurate, the positions and elevations of the salient points were distinctly shown, and his report was highly interesting, and demonstrated the possibility of a railway route.

An undertaking of such magnitude as the construction of a railway over the Andes, at an elevation of 16,000 feet above the sea, was difficult to contemplate; but I was encouraged by the experience I had acquired and the prospect of the immense benefits which my success would confer on the South American States, whenever it should be completed.

I had also to form a company for the construction of a railway from the city of Cordova to the port of Rosario, on the Parana; its terminus being thus in conjunction with the Atlantic.

The entire distance from the Pacific to the Atlantic by the proposed route is about 1000 miles, which may be divided into the following sections, viz.:—

		Miles.
1st.	Rosario to Cordova	250
2nd.	Cordova to the eastern base of the Andes or Fiambala	350
3rd.	The eastern base of the Andes to the junction with the Tres Puntos Railway	320
4th.	The junction with the Tres Puntos Railway to Caldera	80
	Total length	1000 miles.

Rosario, lat. 32° 56′ S., long. 61° 30′ W.
Caldera, lat. 27° 3′ S., long. 70° 55′ W.

I will now examine these sections in their order.

FIRST SECTION—*Rosario to Cordova,* 250 *miles.*—As this portion of the line has been surveyed by Allan Campbell, Esq., I must refer to his Report for particulars.*

The Government of the Argentine Confederation has granted to the Company six miles of land in breadth throughout its entire length. This land is arable and capable of producing cereals, fruits, vegetables, and a superior kind of cotton. It is not excelled as a pastoral or grazing country, and its value must be greatly improved by a railway passing through its centre.

Mr. Campbell has shown in his Report that there is every prospect of its becoming a successful and remunerative line.

SECOND SECTION—*Cordova to the Eastern base of the Andes,* 350 *miles.*—This section is a gradually rising plain, similar in many respects to that of the First Section.

While the First Section embraced the province of Entre Rios and extended to the centre of the province of Cordova, with Buenos

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* This Report has not been received by us, but by a tracing of the line, it appears to pass from Rosario on the Parana to Esquiña, and thence along the high road to Cordova, and thence to La Rioja, near by the line passed by Mr. French in 1826, and laid down on the Map which accompanied his very interesting Paper on the Province of La Rioja, printed in Vol. ix. of this Journal.

Ayres on the south and Santa Fé on the north, this Second Section is continued through the western part of Cordova, Rioja, and Catamarca, and will concentrate the trade of Jujuy, Salta, Tucuman, and Santiago on the north, and that of Mendoza, San Juan, and San Luis on the south; thus showing the central position of the railway as to the whole of the provinces.

Now, without reference to any foreign traffic, we have here 600 miles of railway passing through the centre of this vast region abounding in agricultural, pastoral, and mineral wealth, and forming a grand trunk line at an expenditure which, according to estimates, will not exceed 6000*l.* per mile; and, if we deduct therefrom the value of the lands conceded, the cost of the railway will be greatly reduced: the total concession being 3600 square miles, or 2,304,000 square acres.

THIRD SECTION—*The Eastern base of the Andes to the Junction with the Tres Puntos Railway*, 320 *miles.*—This section is barren and waste, though without doubt rich in mineral wealth, which the railway will develop, but at first must depend for revenue principally from the intercommunication between the eastern and western sides.

Before closing, I may observe that although further investigations may lead to the discovery of a still more favourable route than that proposed, there is one great feature in the Pass of San Francisco which deserves special mention, viz., that travellers cross at all times and seasons over this route, and during the last nine years that I have been connected with Copiapo I have never known it to be closed by snow. I may also quote the opinion of Don Jose Antonio Moreno (a gentleman with whom I have had much intercourse and from whom I have received most accurate information upon all occasions), who has assured me that it offers no difficulty whatever in regard to the snow (probably arising from local circumstances which prevent its drifting).

The following is an extract from the Report and Survey referred to in the foregoing statement by Mr. Wheelwright:—

"According to the tabular section of our survey from Copiapo across the Cordillera, annexed to this Report, it will be seen that the first point at which the gradient begins to assume a serious character is at the junction of the San Andres and Paipote valleys. Here we find water and vegetation, and for 10 miles the surface of the ground is much cut up and broken by the stream passing through it and by the débris from the small ravines on either side. Until we reach Maricunga, after leaving the 10th mile, we find but little or no vegetation and no obstruction to a railway, with the exception of a possible tunnel, 500 feet in length. This tunnel might be found to be unnecessary upon further inspection. Just beyond Maricunga commence the most serious gradients, and a tunnel of more than half a mile in length will be needed to pass from Moreno's valley to the main valley; but the rest of the work to the 'Cuesta de los Chilenos' will be trifling. To pass the Cuesta another tunnel will be needed on a grade of 100 feet to the mile, and its length, for the purposes of estimating, might be stated at 2 miles, although I am inclined to think that an instrumental location would reduce it one-half. We are now on the central plateau of the Andes. From Laguna Salada to the Rio Llama we rise for 18 miles at the rate of 2 feet per mile, and then, according to the table, we have a gradient of 619 feet per mile for 3 miles. This, however, could easily be reduced to 200 feet per mile by projecting the line further to the south and following the bank of the stream—thus increasing the length to 9 miles instead of 3 miles, as it now stands. This heavy gradient has been necessary to reach the plains of Tres Cruces, about 30 miles long and 10 miles broad. We pass through the centre of them over a gently rolling surface for 10 miles, when we bear more to the eastward for the 'Barancas de las Llamas.' These barancas are a spur from the Las Llamas mountains, and extend quite across the plain to the Volcanic range on the other side, and serve as a barrier between the Tres Cruces and Las Llamas plains. In order to rise from one plain to the other, heavy works and rather abrupt gradients would be needed; but an instrumental survey would be necessary to determine the character of this work. From this point we fall gradually to the 'Barancas Blancas,' and then rise again to 'Laguna Verde,' the level of which I have assumed at 14,921 feet above the sea.

"Although the road just described is perfectly practicable, yet a preferable location for gradients, though a more expensive one, could be obtained by keeping more to the north and skirting the base of the Volcanic range with a gradually ascending gradient, and thus overcome part of the rise of the pass of 'San Francisco.' But assuming that it is necessary to pass the level of 'Laguna Verde,' we then have an average rise to the summit of the pass of but 66 feet per mile for 16½ miles. The descending gradient from here to the 'Punto del San Francisco' is 180 feet to the mile; but as the location of the railway would be to the north, keeping up along the base of the mountains, an average gradient of 140 feet per mile would be sufficient, while the extreme gradient for overcoming this pass on a straight line, or in other words, the natural rise of the ground, is in no place over 300 feet per mile. From the great width of the pass it is but reasonable to suppose that the gradient could be much reduced by location.

"From 'El Punto del San Francisco' to Fiambala we find no impediment, with the exception of the passage of the Angostura of the 'Las Losas' river, where the stream descends rather abruptly for 5 miles. But I am led to think that a more thorough examination of the country would endorse the opinion that a better line could be found by leaving the valley of Las Losas at Chouchonil and following another valley that joins the Fiambala valley a short distance above Copacabana, at a town called Puesto.

"I would mention, before closing this description, that we examined the Las Losas Pass, which is about 18 miles from the San Francisco, and although practicable, it is more expensive and not so favourable as the latter. An examination was also made of the Piedra Parada road from Cassadero to Fiambala, without developing any favourable features. This line is next to impossible, as the length of the tunnel required would be 9 miles.

"Gradients of 300 and 500 feet per mile have been worked successfully for some years past with locomotive power, and that also in a country where the snow and ice offer serious impediments. Let us assume the gradient on the 5 miles of line at Maricunga at 480 feet per mile, or 1 foot rise in 11 feet, then $\frac{2240}{11} = 203$; add to this 8 lbs. for friction, and we have 211 lbs. per ton as the amount of force necessary to move 1 ton. According to the experience on the Virginia road, one-sixth of the weight on the driving-wheels can be taken as the effective force, in all weathers, of the locomotive. Assuming our locomotive at 36 tons, and built without trucks, so that the whole weight would be thrown upon the drivers, and carrying its water and fuel upon the top of the boiler, we have 6 tons, or 13,440 lbs. as its effective weight $\frac{13440}{211} = 63$ tons = the load a 36-ton engine without tender could haul over this gradient in all weathers. Thus we see that with a locomotive of this description we can safely rely upon three loaded freight cars passing over these 5 miles at a speed of 5 miles an hour, and allowing 10 working hours per day, one engine could transport over this incline 300 tons of merchandise daily. In this calculation I have made no allowance for curvature, as nothing but absolute location can decide what radii will be necessary.

"I would call attention to the fact that from the Pass of San Francisco to Copiapo the force of gravity could be used as the motive power, and as the freight would principally be in that direction, the gradients would be less objectionable; cattle, sheep, and metals always passing down, while the lighter goods and passenger traffic would depend upon locomotive power.

"The geological and mineralogical deposits of the mountainous districts through which this survey has been conducted may be described as follows:—From Copiapo to the Paipote gate we pass through a rich copper district, and the names of the Ladrillo Garin and Puquios Minerales are not unknown. From this point to the Portezuelo de los Chilenos the country has been but little explored, yet stones were shown me, some rich in copper and others in lead mixed with silver. From the general appearance of the hills, copper should be the predominating metal. I was also promised some specimens of coal; but I am inclined to place but little confidence in the existence of this mineral, principally because of the igneous formation of the country.

"The Chile Cordilleras are divided into two distinct ranges. In the province of Atacama the first range is distant about 40 miles from the coast, and the second about 140 miles. The intervals between these two ranges are occupied by elevated plains, like that between Chanarcillo and Huasco.

"The two ranges of mountains form three distinct geological groups.

"1st. Extending from the sea to the eastern base of the coast range is of the same formation as the Upper Cordilleras.

"2nd. From 20 to 40 miles in width lies in the basin formed between the coast range and the Upper Cordilleras, and overlies the granitic and igneous rocks which probably extend from the coast to the main range. The original formation of this basin was probably shales and argillaceous limestones, which by contact with the igneous rock below and adjoining have become metamorphic porphyries of every colour and description, but usually retaining the stratification of the original formation, although much disturbed by the irruption through them of the underlying igneous rock.

"3rd. Consists of the tertiary and alluvium deposits which were formed subsequently to the upheaval of the mountain ranges. These are found overlying the igneous rock near the coast, part of the stratified formation of Group II. and the metamorphic porphyry of the Upper Cordilleras. Many shells of species now existing in the ocean are found embedded in this group.

"Gold and copper without silver are found in the igneous rocks of Group I. Silver and argentiferous copper in the limestones of Group II.—silver predominating in the limestones and copper in the porphyries. The ores of lead and zinc are frequently found, particularly Galena and Blende; but are not rich in silver, one specimen found on the survey yielding but 30 marks from the assay.

"The Middle Cordilleras are of the igneous formation, and generally unstratified. Sulphur abounds, and is said to be quite pure. On our journey we passed two mountains with many hundred acres of their surface covered with this deposit, while yet another mountain was white with alum. Salt, with which Copiapo is supplied, is taken from the 'Laguna Salada,' on the east side of the 'Portezuelo de Los Chilenos, and, after five days' journey with mules and one day's cartage, is sold in Copiapo at 250 dollars per 100 lbs. This salt could be delivered at Los Chilenos for 50 cents. per 100 lbs., and the action of gravity alone would take it to Copiapo on the railway. The supply is almost inexhaustible, there being at least 50 square miles, or about 150,000 tons on hand, while the formation is perpetually going on.

"The Argentine slope of the Cordilleras, as far as our journey extended, was very similar in its formation to that of Chile—of the same igneous character, and generally granitic. Peculiar species of this rock, of a more or less brilliant red, are found in abundance from Los Piladas to Fiambala; and in many instances a beautiful sandstone, of a similar colour or even still darker, like the Portland freestone, is found joined with it. This stone is stratified and could be easily quarried and used to advantage in the construction of the railway as a building stone.

"The mountains on this slope have been very imperfectly examined for minerals. I was fortunate enough to meet with a 'Cateador' at the 'Punto del San Francisco,' who was in search of a silver 'derotero,' notes of which had been left by the same Spaniard, who was acquainted with the existence of 'Tres Puntas' and the 'Ola.' During his wanderings he had found numbers of copper-veins and veins of other metals with which he had no acquaintance. He also informed me of one vein, 5 feet wide, that answered to the description of coal; but he had never tried any of it with fire. The copper could be worked to advantage with a railway; but at present it is too distant from the sea to be of any use.

"The soil from the Copiapo River to the summit of the Chile Cordilleras is generally sand and gravel, while sufficient earthy matter exists from 'La Puerta del Paipote' to 'Los Chilenos' to support a scanty vegetation, generally a rank grass, similar to that found in salt marshes on the seacoast. The plateau of the Middle Cordilleras is covered with sand and gravel, mixed with volcanic stones, more or less silicious. Grass of the same quality is found where fresh water exists, and also another species, called Pasto Blanco, is sparsely scattered over the plains, furnishing food for the vicuñas and guanacos. The soil on the Argentine slope is also sand and gravel—the former predominating in the valley of the 'Fiambala,' and is of a whitish-grey colour, similar to the sea-beach sand, while gravel is the characteristic of the valley of 'Las Losas.' Owing to the greater abundance of water on the eastern slope, vegetation is quite abundant even at the height of 14,000 feet above the sea. At the Punto del San Francisco we found extensive salt-marches abounding in grass, while even at the summit of the pass the 'Cuerdo de Cabra' furnishes an abundance of firewood of the best quality. At Casedero extensive pastures, 3 and 4 miles in width, commence, and from here to Fiambala there is no lack of vegetation, grass growing in profusion and the small shrubs of the higher altitudes assuming the appearance of trees. We recognised the 'Alga Roba' and Chañar, and were informed that below Fiambala they were of sufficient size to be used for railway sleepers. At Fiambala the soil has all the strength and luxuriance natural to the tropics, at the same time bearing in profuseness the cereals of the more temperate zone, and this, too, without cultivation. The seeds are simply placed in the ground, and no more thought is given to them till the time for harvesting arrives. In fact, we have now arrived at that rich plateau which reaches to the Atlantic Ocean, and although the land still falls toward the east and the mountains hem it in on either side, yet so far as the vegetation is concerned it can be considered as a spur from those immense pampas that extend from the eastern base of the Andes to the sea.

"The climate from Copiapo to Los Chilenos is dry, but growing colder as higher altitudes are reached. Snow falls at 'La Puerta del Paipote' to some extent, and at Los Chilenos it is not uncommonly 2 feet in depth during the winter months; but, owing to the power of the sun and the rarity of the air, it seldom lasts more than one or two days. On the plains of the Cordillera the atmosphere is very rare, often producing pain in the head and nausea, while active exercise is attended with difficulty in respiration. Snow and hail storms are frequent in May, June, and July, and not uncommon in April and August; but, owing to the power of the winds, but a small portion remains upon the plains. On the Argentine slope snow sometimes banks up in the small valley to a height of 15 feet; but on the road by which we passed there is no fear of any impediment of this sort. The climate on this side is more humid than at the same altitudes on the Chile side, rain being quite common at an elevation of 13,000 feet, while at Fiambala, during the winter months, it falls in abundance. I am however led to infer, both from observation and conversation, that the danger to a railway from large freshets would be trifling."

From	To	Miles.
Copiapo	San Andres	65
San Andres	El Bolo	10
El Bolo	Maricunga	24
Maricunga	Los Chilenos	8
Tunnel	3,000 feet, at 250 dollars per foot	·6
Ditto	10,500 feet, ditto	2
Ditto	Laguna Salada	7
Laguna Salada	Rio Llama	18
Rio Llama	Tres Cruces	9
Tres Cruces	Barancas de Las Llamas	15
Barancas de Las Llamas	5-mile Station	5
5-mile Station	Laguna Verde	24
Laguna Verde	San Francisco	16½
San Francisco	Punto S. Francisco	13½
Punto S. Francisco	30-mile Station	30
30-mile Station	Chouchuil	50
Chouchuil	Fiambala	40
		5
	Total Distance	352·6